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TRACER AMMUNITION CONTAINING FERROMAGNETIC MATERIALS AS ADDITIVES  
Effects on Overall Performance

by

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September 1966

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TRACER AMMUNITION CONTAINING FERROMAGNETIC MATERIALS AS ADDITIVES;  
Effects on Overall Performance

by

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## ABSTRACT

A study was made of the effect on tracer ammunition performance of loading tracer mixtures containing ferromagnetic additives under the influence of a magnetic force field.

In a preliminary investigation on the controlled application of magnetic force fields during the loading of tracer ammunition containing tracer compositions with ferromagnetic additives, the quality control of tracer ammunition has been significantly improved. Fifty percent reduction in standard deviations in both total burning time and maximum light intensity were observed, with accompanying increases in maximum light intensity exceeding ten percent.

## INTRODUCTION

There is a continuing need for improvement in quality control procedures for the manufacture of tracer ammunition. One facet of these procedures is the determination of tracer performance by means of burning time and brightness measurements on tracer lots under static conditions. In this investigation, ferric ferrous oxide, a highly ferromagnetic material, was added to a standard tracer composition and the mixture was loaded into tracer cavities in the presence of a magnetic field. It was suspected that uniformity of burning might be obtained because of the tendency of the ferromagnetic additive to line up in the direction of the applied magnetic force field.

In addition to their effects on uniformity of burning rate, additives may have a pronounced effect on both the total burning time and on the brightness spectrum. Several investigators have added metals and metal oxides to explosive and pyrotechnic compositions in an effort to effect desired changes in linear burning (surface recession) rates and maximum brightness. Few, however, have attempted to control the orientation of additives in these compositions. In one such attempt, Baumann et al\* describe the effect of orientation of staples on propellant function.

It was anticipated, in the present investigation, that one effect of adding metal oxide to a tracer composition would be to decrease total burning time since the ferric ferrous oxide would act as a heat sink, absorbing energy which would be reradiated to the reaction zone.

## EFFECTS OF FERROMAGNETIC ADDITIVES

In elements, such as iron, having unfilled electron orbitals, it is found that more electrons spin in one direction than in the other. This imbalance creates what is called a magnetic movement. When the atoms are close and their magnetic movements are great, there is a spontaneous alignment of atoms. This alignment manifests itself as ferromagnetism. The crystals of many materials have magnetic domains and, when these materials are exposed to a magnet, their domains align themselves in one direction, rendering the material magnetic.

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\*Baumann, Bozza, and Hunt, "Orientation of Staples in Fast Burning Propellants (U)," Picatinny Arsenal Report No. 3303, January 1966.

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When these materials are added to tracer compositions, it is conceivable that their aligning motion may have a mechanical effect on the position of other materials in the tracer mixture. This effect may significantly alter the performance of the mixture during burning. Another factor to be considered is the effect of orientation of the ferromagnetic additives on heat transfer across the tracer composition.

The strength of the magnetic field was maintained constant throughout this study.

### PROCEDURE

A relatively intense tracer mixture, R-328, was chosen for use in this investigation. Composition of this mixture is shown in Table I.

TABLE I. Composition of R-328 Tracer Mixture

<u>Ingredient</u>	<u>Weight (%)</u>
Mg (44 microns)	14
Mg (22 microns)	32
SrNO <sub>3</sub>	20
SrC <sub>2</sub> O <sub>4</sub>	4
NaNO <sub>3</sub>	15
Calcium resinate	2
Dechlorane	2.5
KClO <sub>4</sub>	10
Polyethelene	0.5

Mixtures having zero and five different percent (2, 5, 8, 11, and 14) compositions of ferric ferroso oxide and the tracer mixture were blended, loaded in tracer cavities, and fired in preliminary tests to determine which composition would fire with best consistency.

Three rounds of each composition were loaded in 0.296-inch cavities to a pressure of 100,000 psi. Each round contained 48 grains of mixture, with four grains each of I-280 and I-136 (both igniter mixtures) as top-offs. The rounds were subsequently X-rayed and examined under a microscope in an effort to detect the presence of the additive in each mixture. Neither technique was successful, however, since the steel wall of the cavity acted as an effective shield for the mixture.

The rounds were positioned in a static test stand and ignited by a static spark apparatus. Candlepower-time measurements were recorded for each round, using a standard photocell and cathode ray oscilloscope.

On the basis of the reliability and reproducibility shown by the various compositions in these preliminary tests, one composition was chosen for more extensive testing. For this series of tests, the performance of the magnetized and unmagnetized rounds were compared. Two dozen each of magnetized and unmagnetized rounds were loaded and fired. Each round contained 56 grains of tracer mixture and 8 grains of I-280 igniter mixture as a top-off.

The field intensity of the horseshoe magnet, as measured with a gaussometer, was approximately 950 gauss at the estimated point of loading.

## RESULTS

### Preliminary Tests

Total combustion times of tracers tested in the preliminary series of tests are given in Table II.

TABLE II. Combustion Time as a Function of Percent Ferromagnetic Additive

$\text{Fe}_3\text{O}_4$ (%)	Combustion Time (sec)	
	Average	Standard Deviation
0	9.8	1.2
2	9.0	0 <sup>a</sup>
5	8.1	0.8
8	9.0 <sup>b</sup>	
11	9.0 <sup>b</sup>	
14	8.0 <sup>b</sup>	

<sup>a</sup>Based on two rounds; one round burned incompletely.

<sup>b</sup>Only one round functioned; others burned incompletely.

The best performance was yielded by mixtures containing 2% and 5% ferric ferrous oxide. All three of the 5% mixtures burned, while two of the three 2% mixtures burned. On this basis, the 2% and 5% iron oxide tracer mixtures were chosen for testing on a more extensive basis. One dozen each 2% and 5% tracers (magnetized and unmagnetized) and a dozen tracers without metal oxide were loaded for testing.

## Light Intensity Calculations

Upon firing the tracers, maximum light intensity was measured and recorded on Polaroid film from the oscilloscope trace. Vertical distance on the oscilloscope was correlated with foot-candle values on a foot-candle meter at a distance of 17.8 inches from the light source. Figure 1 indicates the relationship between vertical distance on the scope (one centimeter = one square) and candlepower. Each horizontal square represents two seconds on the film.

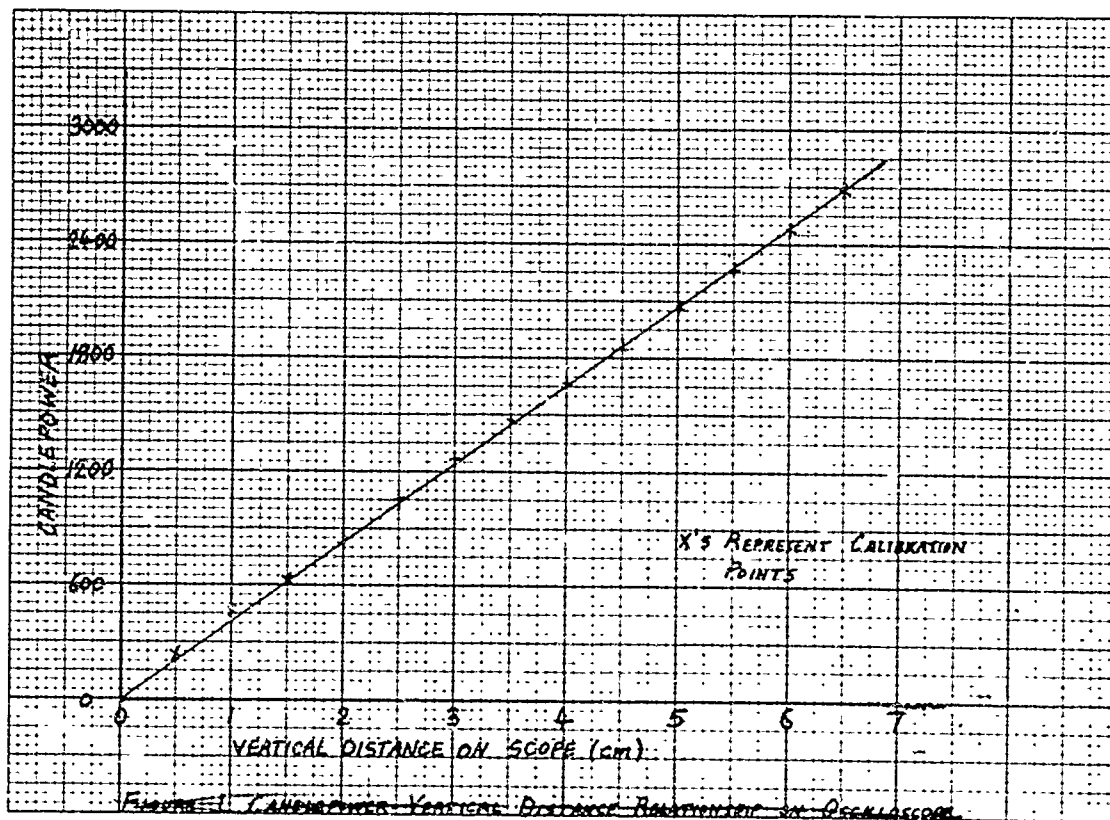


Figure 1. Candlepower-Vertical Distance Relationship on Oscilloscope

## Effects of Magnetized Loading Process

Combustion times, maximum candlepower, and average values and standard deviations of these for each series of tests on the magnetized, unmagnetized, and standard rounds are recorded in Table III. Assuming a normal distribution of data from any one set of conditions, it can be stated that all of the combustion times and maximum candlepower values fall within the limits of the range defined by the mean value, plus or minus three standard deviations. While the number of tests was limited, it must be borne in mind that, with a normal distribution relationship, 99.7 percent of the data should fall within plus or minus three standard deviations from the mean.

TABLE III. Candlepower-Combustion Time Data for  
Magnetized and Unmagnetized Tracer Rounds

<u>Composition</u>	<u>Combustion Time (sec)</u>			<u>Intensity (cp)</u>		
	<u>Range</u>	<u>Mean</u>	<u>Std Dev</u>	<u>Range</u>	<u>Mean</u>	<u>Std Dev</u>
Standard R-328	10.0-12.0	11.35	0.65	1174-2635	1978	437
2% oxide						
Unmagnetized	10.2-11.2	10.8	0.34	1474-2475	1976	436
Magnetized	10.2-11.5	10.7	0.42	1853-2475	2199	265
5% oxide						
Unmagnetized	9.5-10.4	10.0	0.26	1668-2391	2220	205
Magnetized	10.0-10.5	10.1	0.19	1748-2391	1941	221

Failure of microscopic inspection to reveal information concerning the effects of the magnetic field indicates that either the field strength of the magnet was not great enough to make an impression on the tracer mixture or any influence made could only be viewed on a smaller scale. The latter premise would seem to be a more reasonable conclusion to support. X-ray examination of the loaded tracer cores failed to provide any answers because the plates did not show any trace of magnetic orientation.

All tracer mixtures containing the ferric ferroso oxide show somewhat shorter combustion times than the mixture without the oxide. Furthermore, as the percent oxide is increased, the average combustion time decreases, and this relationship appears to be linear over the range of values tested. Because the reaction kinetics and thermodynamics of this system are highly complex, it is not possible to qualitatively identify cause and effect relationships existing among percentage ferric ferroso oxide, combustion time, and light intensity.

With increasing percentages of the oxide, the standard deviations of combustion times of all mixtures tested decreased from 0.65 second for the standard mixture to 0.19 second for 5% oxide. There were no significant differences in either combustion times or standard deviations of combustion times between the magnetized and unmagnetized mixtures. Thus, although there was significant improvement in the quality control of combustion times, this improvement was brought about by the addition of the oxide and not by control of the orientation of the oxide in the mixture.

No discernible differences could be detected in the brightness spectrum between the standard tracer and the mixture containing 2% unmagnetized oxide. However, the 2% magnetized and both 5% mixtures had standard deviations of maximum candlepower equal to one-half of the standard deviation of the R-328 mixture. The 2% magnetized mixture displayed a noticeable improvement over the 2% unmagnetized mixture, both in maximum candlepower and standard deviation of maximum candlepower, the percentage increase in maximum candlepower exceeding ten percent. The 5% magnetized mixture had a maximum brightness approximately ten percent less than the 5% unmagnetized mixture.

There appears to be a contradiction between the trends in maximum candlepower values for the magnetized and unmagnetized series, the magnetized showing decreased values and the unmagnetized increased values with increasing oxide percentage. It appears that the 2% magnetized or 5% unmagnetized mixtures represent optimum conditions with respect to maximum candlepower and minimum deviation of maximum candlepower and combustion time.

Representative candlepower-time curves for each series tested are presented in Figure 2.

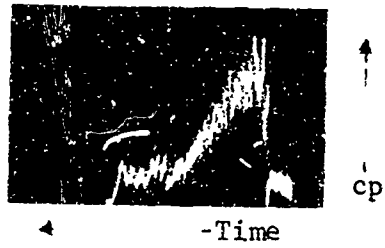
## CONCLUSIONS

1. Loading tracer mixtures containing ferric ferrous oxide (a highly ferromagnetic material) under the influence of magnetic force fields has the effect of significantly reducing standard deviations of both maximum candlepower and total combustion time.

2. The decrease in combustion time of R-328 tracer rounds is directly proportional to the percentage of ferric ferrous oxide in the tracer mixture, regardless of whether or not the tracer round had been loaded in the presence of a magnetic force field.

Standard R-328

TIME: 2 sec/block  
INTENSITY: 415 cp/block

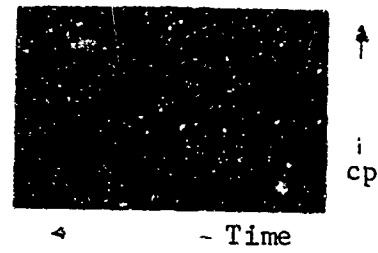


Unmagnetized

2% Oxide



Magnetized



Unmagnetized

5% Oxide



Magnetized

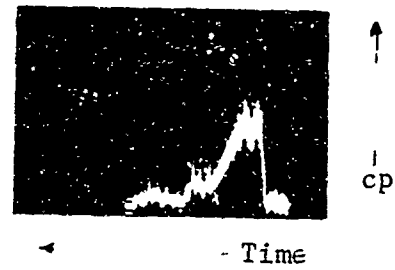


Figure 2. Representative Candlepower-Time Curves

3. The optimum condition encountered in this series of tests was that of the 2% oxide mixture (magnetized). Combustion times, maximum candlepower readings and their respective standard deviations for this condition were  $10.7 \pm 0,4$  seconds and  $2199 \pm 265$  candlepower.

4. The addition of ferromagnetic materials to tracer composition and the subsequent application of a magnetic force field during the loading process can be used to improve the quality control of tracer ammunition performance.

#### RECOMMENDATIONS

It is recommended that this program be continued on a larger scale, including, in addition to tracer compositions, pyrotechnic delay compositions and high explosives.

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